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ON THE POSSIBILITY OF DIRECTLY ACCESSING EVERY HUMAN BRAIN BY ELECTROMAGNETIC INDUCTION OF FUNDAMENTAL ALGORITHMS [1]

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Summary.—Contemporary neuroscience suggests the existence of fundamental algorithms by which all sensory transduction is translated into an intrinsic, brain-specific code. Direct stimulation of these codes within the human temporal or limbic cortices by applied electromagnetic patterns may require energy levels which are within the range of both geomagnetic activity and contemporary communication networks. A process which is coupled to the narrow band of brain temperature could allow all normal human brains to be affected by a subharmonic whose frequency range at about 10 Hz would only vary by 0.1 Hz.

The pursuit of the basic algorithms by which all human brains operate can be considered a central theme of modern neuroscience. Although individual differences are expected to accommodate most of the variance in any specific neurobehavioral measure, there should exist basic patterns of information and structure within brain space. They would be determined by the human genome, i.e., be species-specific, and would contribute to or would serve as the substrate upon which all phenomena that affect neurobehavioral measures are superimposed.

One logical extrapolation to a neurophysical basis of consciousness is that all experiences must exist as correlates of complex but determined sequences of electromagnetic matrices. They would control the theme for the format of cognition and affect while the myriad of possible serial collections of random variations of "noise" within the matrices could potentially differentiate between individual brains. Identification of these sequences could also allow direct access to the most complex neurocognitive processes associated with the sense of self, human consciousness and the aggregate of experiential representations (episodic memory) that define the individual within the brain (Squire, 1987).

The existence of fundamental commonalities between all human brains by which a similar physical stimulus can affect them is not a new concept. It is demonstrated daily by the similar shifts in qualitative functions that are evoked by psychotropic drugs. Classes of chemical structures, crudely classi-

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fied as antidepressant, antipsychotic, or anxiolytic compounds, produce general attenuations of lowered mood, extreme eccentric thinking, or extreme vigilance. The characteristics of these changes are very similar within millions of different human brains regardless of their cultural or genetic history. The idiosyncratic experiences such as the specific thoughts and images which reflect each person's continuing process of adaptation are superimposed upon these general functions. When translated into the language of neuroelectrical domains, the unique components of individual consciousness would be both embedded within and interacting with the species-invariant patterns.

We have been studying the phenomenological consequences of exposure to complex electromagnetic fields whose temporal structures have been derived from the most recently observed neuroelectrical profiles such as burst-firing or long-term potentiating sequences (Brown, Chapman, Kairiss, & Keenan, 1988) which can be considered the prototypical basis of a major domain of brain activity. These temporal patterns of potential codes for accessing and influencing neuronal aggregates have been applied across the two cerebral hemispheres (through the regions of the temporoparietal lobes or within the region of the hippocampal-amygdaloid complex) of the brain as weak electromagnetic fields whose intensities are usually less than 10 milligauss (1 microT). The purpose of this research, as suggested by both E. R. John (1967) and Sommerhoff (1974), is to identify the basic codes for the language of the representational systems within the human brain.

In the tradition of Johannes Mueller, we have assumed that the normal transduction of stimuli by sensors into afferent, graded potentials and the subsequent translation into digital patterns of action potentials (which are more likely to behave functionally as a composite of pixels within a neural field) can be circumvented by *direct* induction of this information within the brain. Induction of complex information would require simulation of the resonance patterns which would normally be transiently created by sensory afferents. The basic premise is that synthetic duplication of the neuroelectrical correlates generated by sensors to an actual stimulus should produce identical experiences without the presence of that stimulus.

We have focused upon the polymodal and most labile portions of the parahippocampal (Van Hoesen, 1982) and entorhinal cortices (Vinogradova, 1975) and the anterior superior gyrus of the temporal cortices (Bancaud, Brunet-Bourgin, Chauvel, & Halgren, 1994) as the region within which circumvention would be most probable. Extraction and translation of neural patterns from different sensory inputs into common codes occur within these regions before they are consciously perceived (Edelman, 1989). That central codes are present was shown by E. R. John (1967, pp. 348-349) who reported an immediate transference of the operant control of a response

from a pulsatile auditory stimulus to a pulsatile visual stimulus if its *temporal pattern* was identical to the previous (acoustic) stimulus.

We (Fleming, Persinger, & Koren, 1994) reported that whole brain exposure of rats to a 5-microT burst-firing magnetic field for 1 sec. every 4 sec. evoked an analgesic response that was similar to that elicited by the application of more noxious, tactile stimulation for 1 sec. every 4 sec. directly to the footpads. Direct electrical stimulation of limbic structures which simulate episodic, systemic application of muscarinic (cholinergic) agents can evoke electrical kindling (Cain, 1989). More recently, direct induction of chaotic electrical sequences within the labile CA1 region of the hippocampus has been shown either to promote or attenuate paroxysmal discharges (Schiff, Jerger, Duong, Chang, Spano, & Ditto, 1994).

These results strongly indicate that imitation of the temporal pattern of sensory transmission directly within the brain by any nonbiogenic stimuli can evoke changes which are just as effective as (and perhaps require less energy than) classical transduction. As stated more recently and succinctly by E. R. John (1990), the fundamental operation of brain electrical activity suggests that some form of frequency encoding may play a significant role in informational transactions within and between brain structures. Consciousness would be associated with an electromagnetic pattern generated by a neural aggregate with invariant statistical features which are independent of the cells contributing to each feature (John, 1990, p. 53).

The effects of applied time-varying magnetic fields upon brain activity have been considered minimal or within the range of normal biological limits unless the intensity of the field exceeded natural endogenous or exogenous (ambient) levels by several orders of magnitude. Until very recently, almost all of the studies from which this conclusion was derived involved highly redundant stimuli such as 60 Hz fields or repetitive pulses. A simple illustration presents the problem: only 1 min. of a 60-Hz sine-wave field exposes a neural net to 3,600 presentations (60 sec. × 60 cycles per sec.) of the *same* redundant information. Even general estimates of habituation (Persinger, 1979) such as the equation $H = IRT^2/R_t$ (IRT = interresponse time, R_t = duration of response) indicate that habituation to the stimulus would have occurred long before its termination after 1 min. Although the burst-firing frequencies (100 to 200 Hz) of the hippocampal neurons, for example, exceed this pattern, they are not temporally symmetrical and exhibit a variability of interstimulus intervals that would contain different information and would attenuate habituation.

The apparent dependence of organismic responses upon the intensity of the applied electromagnetic field, the "intensity-dependent response curve," could simply be an artifact of the absence of biorelevant information within the wave pattern. If the temporal structure of the applied electromagnetic

field contained detailed and biorelevant information (Richards, Persinger, & Koren, 1993), then the intensity of the field required to elicit a response could be several orders of magnitude below the values which have been previously found to elicit changes. For example, Sandyk (1992) and Jacobson (1994) have found that complex magnetic fields with variable interstimulus pulse durations could evoke unprecedented changes in melatonin levels even with intensities within the nanoT range.

The classical counterargument that "very strong" magnetic fields must be present "to exceed or to compensate for the electromagnetic noise associated with intrinsic (Boltzmann) thermal energies" is based upon equations and calculations for the quantitative indices of aggregates of molecular activity and not upon the *pattern* of their interaction. There are other possibilities. For example, Weaver and Astumian (1990) have shown mathematically that detection of very weak electric (microV/cm) fields can occur if the response is exhibited within a narrow band of frequencies; the detection is a function of both thermally induced fluctuations in membrane potential and the maximum increment of change in the membrane potential which is evoked by the applied magnetic field. The ion-cyclotron-resonance model which was initiated by the research of Blackman, Bename, Rabinowitz, House, and Joines (1985) and supported by Lerchl, Reiter, Howes, Honaka, and Stokkan (1991) indicates that, when an alternating magnetic field at a distinct (resonance) frequency is superimposed upon a steady-state magnetic field, the movement of calcium and other ions can be facilitated with very small energies. More than 25 years ago, Ludwig (1968) developed a compelling (but hereto ignored) mathematical argument which described the absorption of atmospherics within the brain.

Above these minimal thresholds, the information content of the wave structure becomes essential. The simplest analogy would be the response of a complex neural network such as a human being to sonic energy. If only a 1000-Hz (sine wave) tone were presented, the intensity required to evoke a response could well exceed 90 db; in this instance the avoidant response would be overt and crude. However, if the structure of the sonic field was modified to exhibit the complex pattern which was equivalent to biorelevant information such as "help me, I am dying," field strengths several orders of magnitude weaker, e.g., 30 db, could be sufficient. This single, brief but information-rich stimulus would evoke a response which could recruit every major cognitive domain.

If the information within the structure of the applied magnetic field is a major source of its neurobehavioral effect, then the "intensity-dependent" responses which are interpreted as support for experimental hypotheses of biomagnetic interaction could be both epiphenomenal and artifactual. Such amplification of electromagnetic-field strengths would also increase the in-

tensity of the extremely subtle and almost always ignored subharmonics, ripples, and other temporal anomalies which are superimposed upon or within the primary frequency. These subtle anomalies would be due to the artifacts within the different electronic circuits and components whose similarities are based upon the fidelity of the endpoint (the primary frequency) despite the different geometries employed to produce the endpoint.

If information rather than intensity is important for interaction with the neural network (Jahn & Dunne, 1987), then *these* unspecified "background" patterns may be the source of both the experimental effects and the failures of interlaboratory replications. A concrete example of this problem exists within the putative association between exposure to power (60 Hz) frequency magnetic fields and certain types of cancer. The existence of these transients, often superimposed upon the fundamental 60-Hz frequency, is still the least considered factor in the attempts to specify the characteristics of the fields which promote aberrant mitosis (Wilson, Stevens, & Anderson, 1990).

Within the last five years, several researchers have reported that direct and significant effects upon specific neuropatterns can be evoked by extremely weak magnetic fields whose intensities are within the range of normal geomagnetic variations. Sandyk (1992) has discerned significant changes in vulnerable subjects such as patients who were diagnosed with neurological disorders following exposures of short durations to magnetic fields whose strengths are within the pT to nT range but whose spatial applications are multifocal (a fasces-type structure) and designed to induce heterogeneous patterns within a very localized brain space. The effective components of the field (which are assumed to be discrete temporal patterns due to the modulation of the frequency and intensity of the electromagnetic fields) are not always obvious; however, the power levels for these amplitudes are similar to those associated with signals (generated globally by radio and communication systems) within which most human beings are exposed constantly.

The most parsimonious process by which all human brains could be affected would require (1) the immersion of all of the approximately 6 billion brains of the human species within the same medium or (2) a coercive interaction because there was facilitation of a very narrow-band window of vulnerability within each brain. For the first option, the steady-state or "permanent" component of the earth's magnetic field meets the criterion. The possibility that masses of susceptible people could be influenced during critical conditions by extremely small variations (less than 1%) of the steady-state amplitude (50,000 nT) of the earth's magnetic field such as during geomagnetic storms (50 to 500 nT) has been discussed elsewhere (Persinger, 1983). Recent experimental evidence which has shown a threshold in geomagnetic activity of about 20 nT to 30 nT for the report of vestibular

experiences in human beings and the facilitation of limbic seizures in rodents is consistent with this hypothesis.

The potential for the creation of an aggregate process with gestalt-like properties which reflect the average characteristics of the brains that are maintained with this field and that generate the aggregate has also been developed (Persinger & Lafreniere, 1977) and has been labelled the "geopsyche." This phenomenon would be analogous to the vectorial characteristics of an electromagnetic field which is induced by current moving through billions of elements such as wires contained within a relatively small volume compared to the source. Such gestalts, like fields in general, also affect the elements which contribute to the matrix (Freeman, 1990).

The second option would require access to a very narrow limit of physical properties within which all brains are maintained to generate consciousness and the experience of self-awareness. This factor would be primarily loaded by the variable of brain temperature. Although the relationship between absolute temperature and wavelength is generally clear [an example which can be described by Wien's law and is well documented in astrophysics (Wyatt, 1965)], the implications for access to brain activity have not been explored. The fragile neurocognitive processes that maintain consciousness and the sense of self normally exist between 308°K and 312°K (35°C and 39°C). The fundamental wavelength associated with this emission is about 10 micrometers which is well within the long infrared wavelength.

However, the ratio of this normal range divided by the absolute temperature for normal brain activity which maintains neurocognitive processes is only about 0.013 (4°K/312°K) or 1.3%. If there were a subharmonic pattern in naturally occurring or technically generated magnetic fields which also reflected this ratio, then all brains which were operative within this temperature range could be affected by the harmonic. For example, if 11.3 Hz were one of these subharmonic electromagnetic frequencies, variations of only 1.3% of this mean, i.e., 11.3 Hz ± 0.1 Hz, would hypothetically be sufficient to affect the operations of all normal brains. If this "major carrier frequency" contained biorelevant information by being modulated in a meaningful way, then the effective intensities could be well within the natural range for background radiation (microwatts/cm^2) and could be hidden as chaotic components within the electromagnetic noise associated with power generation and use.

One of the major direct prophylactics to the effects of these fields would require alterations in core (brain) temperature such as deep but reversible hypothermia. However, this condition would disrupt the biochemical process upon which neuronal activity and hence consciousness depends. Treatments which precipitate alterations in neural activity, similar to those which are associated with crude hypothermia, would be less disruptive.

Specific candidates which affect multiple receptor systems such as clozepine (Clozaril) and acepromazine could be possible pharmacological interventions.

The characteristics of the algorithm for euthermic individuals are likely to be conspicuous (once isolated) but should now be hidden within the synchronous activity which is (1) modified and filtered by aggregates of neurons and (2) modulated by sensory inputs and intrinsic oscillations (Kepler, Marder, & Abbott, 1990) before they are crudely measured by electrodes. Because the fundamental algorithm would be essentially a stable parameter of body temperature, most electrode montages (including monopolar to a nonbrain reference, e.g., ear) would cancel or attenuate this index. Effectively, the algorithm would be expressed in a manner similar to descriptors for other aggregate phenomena as a physical constant or as a limited set of these constants. This suggestion is commensurate with the observation that the underlying neuronal networks which coordinate millions of neurons manifest the properties of a (mathematical) strange attractor with a very limited number of degrees of freedom (Lopes, Da Silva, Kamphuis, Van Neerven, & Pijn, 1990).

The physical chemical evidence for a fundamental process, driven by a narrow limit of biological temperature, has been accumulating. Fixed, oscillatory electromagnetic variations have been shown *in vitro* for enzymes of the glycolytic pathway (Higgins, Frenkel, Hulme, Lucas, & Rangazas, 1973) whose narrow band of temperature sensitivity (around 37°C) is well known. Although these oscillations are often measured as periods (2.5-min. cycles), Ruegg (1973) reported a clear temperature dependence of these oscillations within the range of 1 to 20 Hz between 20°C and 35°C in invertebrate muscle.

The most probable brain source which might serve as the primary modulatory of these biochemical oscillators would involve structures within the thalamus (Steriade & Deschenes, 1984). Neuronal aggregates with surprisingly fixed (within 0.1-Hz) oscillations are found within this structure and depend primarily upon neurons that require gamma amino butyric acid or GABA (von Krosigk, Bal, & McCormick, 1993). This inhibitory amino acid is specifically derived from the normal, temperature-sensitive degradation of glucose by the GABA shunt (Delorey & Olsen, 1994).

Within the last two decades (Persinger, Ludwig, & Ossenkopp, 1973) a potential has emerged which was improbable but which is now marginally feasible. This potential is the technical capability to influence directly the major portion of the approximately six billion brains of the human species without mediation through classical sensory modalities by generating neural information within a physical medium within which all members of the species are immersed. The historical emergence of such possibilities, which have

ranged from gunpowder to atomic fission, have resulted in major changes in the social evolution that occurred inordinately quickly after the implementation. Reduction of the risk of the inappropriate application of these technologies requires the continued and open discussion of their *realistic* feasibility and implications within the scientific and public domain.

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